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This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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Additional inventors are being named on the 2 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Apparatus for spinal fixation of vertebra

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 18

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Respectfully submitted,

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Number 1 of 1

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APPARATUS FOR SPINAL FIXATION OF VERTEBRAE

FIELD OF THE INVENTION

The present invention relates to the field of devices and methods for facilitating the performance of computer assisted surgery on a number of vertebrae in a single procedure, and especially using robotic execution of the procedure.

BACKGROUND OF THE INVENTION

In a conventional surgical operation, the surgeon operates on an organ using his visual and tactile senses in order to locate his hand and the surgical tool in the correct position. In Computer Assisted Surgery (CAS) however, the motion of the surgical tool is generally determined by a pre-operative plan, with the actual operating location being pre-planned using pre-operative X-ray, CT, MRI or other images. During the operation, it is necessary to transfer this planning information to the operation site, generally by mutually referencing the coordinate system of the patient, the position of the surgical tool and the data provided by the pre-operative plan. This is known as a registration procedure.

It is therefore important to provide the computer with accurate information concerning the patient position relative to the navigation/robotic system. This is accomplished in contemporary CAS devices by either holding the organ on which the operation is being performed, in a fixed position following the registration process, or by attaching a dynamic referencing device which moves with the organ being operated on, and compensates for undesired motion by means of dedicated tracking software.

In spinal operation CAS procedures, if the procedure is to be performed on more than one vertebra, it is necessary, according to prior art methods, to affix a dynamic referencing sensor at each level of the spine, or even on each vertebra, so that relative motion between different regions of the spine or even between

different vertebrae can be detected and compensated for. Alternatively, all of the vertebra to be operated on are fixed to a stationary frame to ensure well-defined positions. Both of these alternatives are complex or inconvenient procedures.

There therefore exists an important need to provide a method of enabling CAS to be performed on several vertebrae in a single procedure, by means of a simple apparatus.

Additionally, when surgery is to be performed to correct or treat conditions related to spinal curvature, according to prior art methods, the surgeon has generally used visual means for estimating the position of the vertebrae at different levels of the back.. Such visual estimation, whether based on manual manipulation of the operating tools, or CAS guidance thereof, is potentially inaccurate and highly dependent on the surgeon's skill. There therefore also exists a need to provide a reference method for providing the surgeon with information about the relative location of vertebrae over the whole length of the spine.

SUMMARY OF THE INVENTION.

There is thus provided, according to various preferred embodiments of the present invention, novel framed devices for use in fixing a number of vertebrae together into positions which are uniquely defined relative to the frame. Such fixation is especially useful in two applications of spinal surgery:

(i) as a reference frame for Computer Assisted Surgery procedures performed on a number of vertebrae of the spine in one procedure, either using manual navigation and a tracking system to follow the position of the surgeon's tools relative to the operated vertebrae, or by using a pre-programmed robot to perform the surgery; and

(ii) as a reference frame for use in performing surgical procedures at locations along the entire length of the spine of a subject, or a major part thereof, when it is necessary to provide a reference for alignment of major lengths of the spine or all of the spine.

According to a first preferred embodiment of the present invention, there is provided a reference bridge that fixes several vertebra together to generate a single frame of reference for all of those vertebrae. This bridge differs from prior art vertebrae fixing devices in that although it is fixed above the spine and relative to the vertebrae, it is allowed to move with movement of the spine, as a single unit in space relative to the operating table. A dynamic referencing sensor, a miniature robot or a passive measuring arm operating as a mechanical digitizer, can be attached to this reference bridge, and since each of the relevant vertebrae are affixed to the bridge, a registration procedure can be used to define the relative position and orientation of each of the vertebra and of the frame itself, relative to the operation planning environment, whether a preoperative CT or MRI image, or an intra-operative X-ray fluoroscopic image, or any other. This thus obviates the prior art need either for individual registration of each vertebra, or for fixing of all of the vertebrae relative to the operating table. It is to be understood that terms such as "above the spine" or "above a vertebra", or similar, as used in this application, and as claimed, are not meant to define a position in absolute space, but rather to indicate a general disposition relative to the spine or vertebrae when the subject is supine, which is the usual position for performing such surgical procedures.

Once their relative position is known, the vertebrae can then be accurately operated upon, either using a navigation system or a bone mounted or bridge mounted robot. The preferred use of a bone or bridge mounted robot is an advantageous embodiment because it obviates the need to know where the vertebrae are relative to the environment, it being concerned only with the relative position of the vertebrae to each other and to the bridge. According to another preferred embodiment of the present invention, the bridge is used with a navigation system external to the bridge, in which the bridge ensures that the referencing to each vertebrae is known, not only relative to each other vertebra, but also absolutely in space, and hence relative to the external navigation system. In such embodiment, a tracking system is used to ensure correct positioning of the surgeon's tools relative to the bridge and hence to each vertebra.

When utilized for executing the first group (i) of applications mentioned hereinabove, a bridge according to the present invention, is operative in the fixation of the positions of several, generally adjacent or closely spaced vertebra to the bridge. When utilized for executing the second group (ii) of applications mentioned hereinabove, the bridge takes the form of a long frame extending from the pelvis to the skull, preferably with fixation at the skull and the pelvis, and at several selected vertebral points between them.

There are several indications in which the present invention can be advantageously applied, the indications being listed according to the spinal region of their application:

A. SURGICAL INDICATIONS FOR THE CERVICAL REGION

1.Atlantoaxial Instability, (C1-C2 Injuries)-Magerl technique of transarticular C1-C2 screw fixation.

2. Radiculopathy, when present, due to entrapment of an exiting nerve root within a collapsed neuroforamen.

3.Syndrom a vertebralis due to segmental cervical spine instability.

4. Fractures of vertebral bodies.

5. Spinal vertebral body tumor, with adjacent vertebral body fusion recommended.

6. Failed decompressive operations with syndrome of cervical spine instability (status post laminectomy).

B. SURGICAL INDICATIONS FOR THE THORACIC AND LUMBAR REGIONS

1. Mechanical back pain.

2. Radiculopathy, when present, is due to entrapment of an exiting nerve root within a collapsed neuroforamen.

3. Spondylolisthesis.

4. Fractures of vertebral bodies

5. Spinal vertebral body tumor with adjacent vertebral body fusion recommended.

6. Failed previous fusion (pseudoarthrosis).

7. Failed decompressive operations with syndrome of lumbar spine instability.
8. Scoliosis

There is therefore provided in accordance with a preferred embodiment of the present invention, a bridge for use in orthopaedic surgery on the spine of a subject, the spine comprising a plurality of vertebrae, the bridge comprising a first support member attached at one end to a first vertebra in the spine of the subject, at least a second support member attached at one end to a second vertebra in the spine of the subject, and a cross member attached to the first and second support members at positions remote from the vertebra attachment ends of the support members, such that the cross member is positioned proximate at least the first and the second vertebrae, wherein the bridge is free to move with movement of the spine of the subject.

According to a further preferred embodiment, the bridge may also comprise at least one additional support element attaching the cross member to at least one additional vertebra of the spine, such that the first vertebra, the second vertebra and the at least one additional vertebrae are fixed into positions which are uniquely defined relative to the bridge. The at least one additional support element may preferably be a K-wire. The bridge, the first vertebra, the second vertebra, and the at least one additional vertebrae of the spine, may thus move conjointly relative to the external environment.

In accordance with still another preferred embodiment of the present invention, in the above-described bridge, the bridge member may preferably be such as to accommodate a surgical robot at any of a plurality of predefined positions along its length, such that the robot can perform surgical procedures on a plurality of the vertebrae. The robot is thus able to perform the surgical procedures on a plurality of the vertebrae with a single registration process. Alternatively and preferably, a surgical robot may be attached to one of the vertebrae, such that the robot can perform surgical procedures on a plurality of the vertebrae with a single registration process.

According to still another preferred embodiment of the present invention, the bridge can be provided with a navigational position probe associated with an

external computer assisted surgery system, such that the position of the bridge and of the vertebrae are known to the system.

There is further provided in accordance with yet another preferred embodiment of the present invention, a bridge for use in orthopaedic surgery on the spine of a subject, the spine comprising a plurality of vertebrae, the bridge comprising a first bridge support arrangement adapted to attach a first end of the bridge to the pelvic bone structure of the subject, at least a second support arrangement adapted to attach a second end of the bridge to the skull of the subject, and at least one additional support arrangement disposed intermediate the first and second ends of the bridge, the at least one additional support arrangement being adapted to attach the bridge to at least one vertebra of the spine, wherein the support arrangements are such that the bridge is positioned proximate the vertebrae of the spine and is free to move with movement of the spine of the subject. According to a further preferred embodiment, the at least one additional support arrangement preferably comprises two additional support arrangements, such that the bridge comprises lumbar, thoracic and cervical sections. The vertebrae of the spine and the bridge are thus free to move conjointly relative to the external environment.

In accordance with still another preferred embodiment of the present invention, in the above-described bridge, the bridge may preferably be such as to accommodate a surgical robot at any of a plurality of predefined positions along its length, such that the robot can perform surgical procedures on a plurality of the vertebrae. The robot is thus able to perform the surgical procedures on a plurality of the vertebrae with a single registration process. Alternatively and preferably, a surgical robot may be attached to one of the vertebrae, such that the robot can perform surgical procedures on a plurality of the vertebrae with a single registration process.

According to still another preferred embodiment of the present invention, the above-described bridge can be provided with a navigational position probe associated with an external computer assisted surgery system, such that the position of the bridge and of the vertebrae are known to the system.

The disclosures of the publications mentioned in this section and in other sections of the specification, are hereby incorporated by reference, each in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Fig.1 is a schematic illustration of the whole of a subject's spine, showing two reference bridges, constructed and operative according to various preferred embodiments of the present invention;

Fig. 2 illustrates schematically a view of a lumbar section of a subject's spine, showing a bridge, constructed and operative according to a first preferred embodiment of the present invention, connecting a number of lumbar vertebrae together;

Fig. 3 is a schematic illustration of a lumbar section of subject's spine, showing a bridge, similar in function to that of the embodiment of Fig. 2, but constructed and operative according to another preferred embodiment of the present invention;

Fig. 4 is a schematic illustration of the lumbar section of a whole spine bridge, showing the component parts for anchoring the lumbar section to the subject's pelvis;

Fig. 5 is an overall view of the lower end of the whole spine bridge showing its disposition when fixed to the subject's pelvis and spine; and

Figs. 6 and 7 schematically show preferred embodiments of the whole spine bridge described in the embodiments of Figs. 4 and 5, but with a miniature surgical robot attached thereto; Fig. 6 shows the robot mounted on the thoracic section of the bridge, while Fig. 7 shows the robot mounted on the lumbar section of the bridge.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now made to Fig. 1 , which is a schematic illustration of the whole of a subject's spine, showing two reference bridges, constructed and operative according to various preferred embodiments of the present invention, for facilitating the performance of surgical procedures on the spine 10 of the subject. The illustration shows a first reference bridge 12 connecting a number of lumbar vertebrae 14 for enabling treatment in a single procedure, as mentioned in application (i) hereinabove, and a second reference bridge 16, composed of several sections, preferably connected to a number of vertebrae 18 along the entire length of the spine, as well as to the skull 20 and the pelvis 22, as mentioned in application (ii) hereinabove. It is to be understood that the two bridges shown can generally be used either as one connected system with no mutual relative motion or separately Each of these embodiments is now described in more detail in the drawings to follow.

Reference is now made to Fig. 2, which illustrates schematically a view of a lumbar section of a subject's spine, showing a bridge, constructed and operative according to a first preferred embodiment of the present invention, connecting a number of lumbar vertebrae together. Though this embodiment is illustrated in connection with the lumbar vertebrae, it is to be understood that it is applicable to groups of vertebrae at any level of the back. In the preferred example illustrated, the bridge 12, comprising a cross member 30 with referencing holes 32, and two vertical support arms 34, is connected to the spinous processes of four adjacent vertebrae 14. Two preferred methods of attachment are shown in Fig. 2, the support arms 34 being attached by means of clamps 36 onto the spinous processes of the outer pair of vertebrae, while the inner vertebrae are connected to the cross member 30 by means of 1.5-2mm K-wires 38 attached to their corresponding spinous processes.

Once the bridge has been mounted onto the vertebrae to be treated, the cross member 30 constitutes a platform disposed close to and above the spine, and which has a fixed position relative to each of the vertebrae, and moves in

absolute space together with the vertebrae. As described hereinabove, a preliminary registration procedure, as known in the art, can be performed to define the relative position and orientation of each of the vertebra relative to the frame itself, by means of dynamic referencing sensors, or a passive measuring arm operating as a mechanical digitizer. Once this has been done, the position of each of the vertebrae is known relative to the bridge, and if suitable pre-registration fiducials have been used, also of the bridge itself relative to the operation planning environment, whether a preoperative CT or MRI image, or an intra-operative X-ray fluoroscopic image, or any other image. According to one preferred method of use of the bridge of this embodiment, a miniature surgical robot, such as that described in co-pending US Patent Application Serial Number 09/912,687, by some of the inventors of the present application, may be attached to one or more of the referencing holes 32. Such a miniature robot is then able to utilize the registration information to perform accurately positioned procedures, such a screw hole drilling, on each of the vertebrae in succession, regardless of whether the subject moves between the procedures on the successive vertebrae. This thus enables such procedures to be performed more conveniently and comfortably than by means of prior art methods, where either each vertebra is registered and operated on independently, or alternatively, if they are connected preoperatively, the subject is fixed relative to the operating table to render the connected vertebrae immobile.

According to another preferred procedure, the operation may be performed by a surgeon using hand-held tools, and an external tracking system used to relate the position of these tools to the position of the bridge and each of the vertebrae, and to the operation environment, whether predetermined by preliminary imaging, or determined intra-operatively.

Reference is now made to Fig. 3, which is a schematic illustration of a lumbar section of subject's spine, showing a bridge, similar in function to that of the embodiment of Fig. 2, but constructed and operative according to another preferred embodiment of the present invention. Features common to those of Fig. 2 are labeled with the same reference characters. The bridge shown in Fig. 3

differs from that shown in Fig. 2 in that the cross member 40 of the bridge has a series of flat surfaces 42, with mounting holes 44 which are located to match the mounting holes of the base 48 of a miniature surgical robot 46, of the type shown below in Figs. 6 and 7. shown in Fig. 3 ready for mounting onto the center position of the bridge. Such a preferred mounting method makes it particularly simple to move the robot from position to position when needed, while maintaining the accuracy of the registration. Though the robot in Fig. 3 is shown without any operating tools attached to its working platform 50, it is to be understood that any such tools may be attached thereto, as described in the prior art.

The bridge of Fig. 3 also shows another preferred method of attachment to the vertebrae, whereby the center of the bridge is attached by means of a clamp, and the outer ends by means of K-wires attached to the spinous processes of the pouter vertebrae.

Reference is now made back to Fig. 1, in order to describe details of the construction and operation of the whole-spine bridge, according to another preferred embodiment of the present invention. The bridge, according to this embodiment, can preferably be divided into three separate joined component sections – a lumbar section, a thoracic section and a cervical section. It is to be understood however, that this division is only one convenient manner of constructing such a bridge, and the present invention is not meant to be limited thereby. Other preferred constructions can also be envisaged, and even partial spine bridges, where not all three sections of the spine are included.

Reference is now also made to Figs. 4 and 5, which show further details of the lower end of the whole spine bridge and which are to be viewed together with the details shown in Fig. 1. Fig. 4 is a schematic illustration of the lumbar section of the bridge, showing the component parts for anchoring this section to the subject's pelvis. Fig. 5 is an overall view of the lower end of the bridge showing its disposition when fixed to the subject's pelvis and spine. The lumbar bridge section 60 preferably comprises two nails 62 with screwed ends, inserted into the spina iliaca posterior superior on both right and left sides of the subject. A bar 66

is preferably attached to both screwed nails 62, in order to generate a rigid connection between the two nails, to serve as a base anchor for the lumbar section 60 of the spinal bridge. The upper end of the lumbar section of the bridge is preferably attached to a spinous process of one of the upper lumbar vertebrae, either by means of a clamp 68 as shown in Fig. 5, or by means of a K-wire 70, shown in Fig. 4, drilled into such a suitably located spinous process in the lumbar spine region. The lumbar bridge section and its component parts are preferably attached to each other by means of adjustable fittings, such that the disposition of the bridge relative to the spine can be performed with maximum flexibility to suit individual subjects.

Attached to the bridge is a sliding carriage 72, that can be moved to any desired position along the lumbar section of the bridge, and rigidly locked by means of a thumbscrew 74 above the lumbar spine region of interest. A robotic system or a dynamic referencing probe can be attached to the sliding carriage, and thus positioned at several defined orientations in order to reach any desired location along the lumbar spine. The miniature surgical robot or a dynamic referencing sensor can preferably be mounted on the platform of the carriage, in a manner similar to that described for the vertebral bridge of the embodiments shown in Figs. 2 and 3 hereinabove.shown in Figs. 6 and 7 hereinbelow.

Referring now to Fig. 5 again, the thoracic section 76 of the bridge is connected at its lower end to the lumbar section 60, and at its upper end by means of one or more clamps 78 to the spinous processes of one or more chosen vertebrae from the thoracic spine region. Alternatively and preferably, though not shown specifically in Fig. 5, one or more 1.5-2 mm K-wires are drilled into one or more chosen vertebrae from the thoracic spine region, in the same manner as for this use of K-wires with the lumbar vertebrae. Attached to the bridge is a sliding carriage, similar to that described above, which can be moved to any desired position along the thoracic section of the bridge, and rigidly locked by means of a thumbscrew above the region of interest. A robotic system or a dynamic referencing probe can be attached to the sliding carriage, and thus positioned at several defined orientations in order to reach any desired location

along the thoracic spinal region. The miniature surgical robot can preferably be mounted on the platform of the carriage, in a manner similar to that described for the vertebral bridge of the embodiments of Figs. 2 and 3 hereinabove.shown in Figs. 6 and 7 hereinbelow.

Finally, the cervical section of the bridge 80 is shown, referring also back to Fig. 1. A halo ring 82 or another similar commonly used fixing device, is rigidly attached on the subject's skull 20. The upper end of the cervical section 80 of the bridge is preferably supported by attachment to the halo ring 82. The lower end is supported either by attachment to the upper end of the thoracic section 76 of the bridge, or by means of a clamp or one or more K-wires to spinous processes suitably located near the lower cervical region. As with the lumbar 60 and thoracic bridge 76 sections, a sliding carriage 72 is preferably attached to the bridge, and can be moved to any desired position along the thoracic section of the bridge, and rigidly locked by means of a thumbscrew 74 above the region of interest. A robotic system or a dynamic referencing probe can be attached to the sliding carriage, and thus positioned at several defined orientations in order to reach any desired location along the thoracic spinal region. The miniature surgical robot 46 can preferably be mounted on the platform of the carriage, in a manner similar to that described for the vertebral bridge of the embodiments of Figs. 2 and 3 hereinabove shown in Figs. 6 and 7 hereinbelow.

The cervical section of the bridge is preferably profiled to have the same approximate shape 84 as the cervical lordosis, such that the operating point of the robot mounted on the carriage remains close to the point of operation on the subject's spine.

Although in the preferred embodiment of the spinal bridge shown in Figs. 1 and 5, the thoracic section 76 of the bridge is shown anchored to the ends of the cervical 80 and lumbar 60 sections, it is to be understood that the invention is not meant to be limited thereby, but that any suitable connection scheme may be used, whereby the ends of each section of the bridge are firmly connected to their neighboring section's ends, where applicable, such that all of the sections of the

bridge form one rigid structure generally parallel to the line of the spine, and are also firmly disposed relative to the vertebrae of the spine. Thus, for example, according to another preferred embodiment of the present invention, either or both ends of the thoracic section could preferably be connected directly to vertebrae, and the cervical and lumbar sections attached to the thoracic section. Furthermore, although the invention has been described using all three sections of the whole-spine bridge, it is to be understood that the invention is not meant to be limited thereby, but that embodiments using two adjacent sections of the three described are also meant to be included as preferred embodiments of the present invention.

Whole spine bridges have been used previously for Halofemoral longitudinal and pelvic traction for spinal deformity correction. The above described spinal bridge of the present invention can preferably be used for surgical correction of spinal deformities, such as for example, scoliotic deformity, by improving the anatomical relationships between vertebrae, and by improving the accuracy with which screw insertion is made into the pedicle for attaching inserts for correcting such deformities. Additionally, the present invention may also be advantageous for providing increased accuracy in robotic screw insertion, by the reduction in mutual movement of adjacent vertebrae, which may result in degraded screw insertion accuracy.

Reference is now made to Figs. 6 and 7, which schematically show preferred embodiments of the whole spine bridge described in the embodiment of Fig. 5, but with a miniature surgical robot 82 of the type described in co-pending US Patent Application Serial Number 09/912,687, attached thereto.

In Fig. 6, the robot 82 is shown attached by its base 84 to the adjustable platform 72 on the thoracic section 76 of the bridge. The top plate 86 of the robot shown is the surface whose motion is controlled by the robot actuators, and to that surface is preferably attached a tool frame 88, which in the embodiment shown, carries a drill guide 90 for positioning the surgeon's drill accurately where required by the operation plan. In Fig. 7, according to another preferred embodiment of the present invention, the robot 82 is shown attached by its base

84 to the adjustable platform 72 on the lumbar section 76 of the bridge. The top plate 86 of the robot shown is the surface whose motion is controlled by the robot actuators, and to that surface is preferably attached a tool frame 88, which in the embodiment shown, carries a drill guide 90 for positioning the surgeon's drill accurately where required by the operation plan.

It is appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention includes both combinations and subcombinations of various features described hereinabove as well as variations and modifications thereto which would occur to a person of skill in the art upon reading the above description and which are not in the prior art.

CLAIMS

We claim:

1. A bridge for use in orthopaedic surgery on the spine of a subject, said spine comprising a plurality of vertebrae, said bridge comprising:

a first support member attached at one end to a first vertebra in said spine of said subject;

at least a second support member attached at one end to a second vertebra in said spine of said subject; and

a cross member attached to said first and second support members at positions remote from said vertebra attachment ends of said support members, such that said cross member is positioned proximate at least said first and said second vertebrae;

wherein said bridge is free to move with movement of said spine of said subject.

2. A bridge according to claim 1, and also comprising at least one additional support element attaching said cross member to at least one additional vertebra of said spine, such that said first vertebra, said second vertebra and said at least one additional vertebrae are fixed into positions which are uniquely defined relative to said bridge.

3. A bridge according to claim 2, and wherein said at least one additional support element is a K-wire.

4. A bridge according to either of claim 2 and 3, and wherein said first vertebra, said second vertebra, said at least one additional vertebrae of said spine, and said bridge are free to move conjointly relative to the external environment.

5. A bridge according to any of claims 1 to 4, and wherein said bridge member is adapted to accommodate a surgical robot at any of a plurality of predefined positions along its length, such that said robot can perform surgical procedures on a plurality of said vertebrae.

6. A bridge according to claim 5, and wherein said robot is able to perform said surgical procedures on a plurality of said vertebrae with a single registration process.

7. A bridge according to any of claims 1 to 4, and also comprising a surgical robot attached to one of said vertebrae, such that said robot can perform surgical procedures on a plurality of said vertebrae.

8. A bridge according to claim 7, and wherein said robot is able to perform said surgical procedures on a plurality of said vertebrae with a single registration process.

9. A bridge according to any of claims 1 to 4, and also comprising a navigational position probe associated with an external computer assisted surgery system, such that the position of said bridge and of said vertebrae are known to said system.

10. A bridge for use in orthopaedic surgery on the spine of a subject, said spine comprising a plurality of vertebrae, said bridge comprising:

a first bridge support arrangement adapted to attach a first end of said bridge to the pelvic bone structure of said subject;

at least a second support arrangement adapted to attach a second end of said bridge to the skull of said subject; and

at least one additional support arrangement disposed intermediate said first and second ends of said bridge, said at least one additional support

arrangement being adapted to attach said bridge to at least one vertebra of said spine;

wherein said support arrangements are such that said bridge is positioned proximate said vertebrae of said spine and is free to move with movement of said spine of said subject.

11. A bridge according to claim 10, and wherein said at least one additional support arrangement comprises two additional support arrangements, such that said bridge comprises lumbar, thoracic and cervical sections.

12. A bridge according to either of claims 10 and 11, and wherein said vertebrae of said spine and said bridge are free to move conjointly relative to the external environment.

13. A bridge according to any of claims 10 to 12, and wherein said bridge is adapted to accommodate a surgical robot at any of a plurality of predefined positions along its length, such that said robot can perform surgical procedures on a plurality of said vertebrae.

14. A bridge according to claim 13, and wherein said robot is able to perform said surgical procedures on a plurality of said vertebrae with a single registration process.

15. A bridge according to any of claims 10 to 12, and also comprising a surgical robot attached to one of said vertebrae, such that said robot can perform surgical procedures on a plurality of said vertebrae.

16. A bridge according to any of claims 10 to 12, and also comprising a navigational position probe associated with an external computer assisted surgery system, such that the position of said bridge and of said vertebrae are known to said system.

ABSTRACT

A framed device in the form of a bridge for fixing a number of vertebrae together into positions which are uniquely defined relative to the bridge, but which can move relative to the external environment. The fixation generated by such a bridge is especially useful in Computer Assisted Surgery procedures, either using manual navigation and a tracking system to follow the position of the surgeon's tools relative to the operated vertebrae, or by using a pre-programmed robot mounted on the bridge itself to perform the surgery. Alternative embodiments of the bridge may be used either for performing surgery in one procedure on a number of vertebrae of the spine, or as a reference frame for performing surgery at different locations along the spine, while providing an alignment reference along major lengths or along all of the spine.

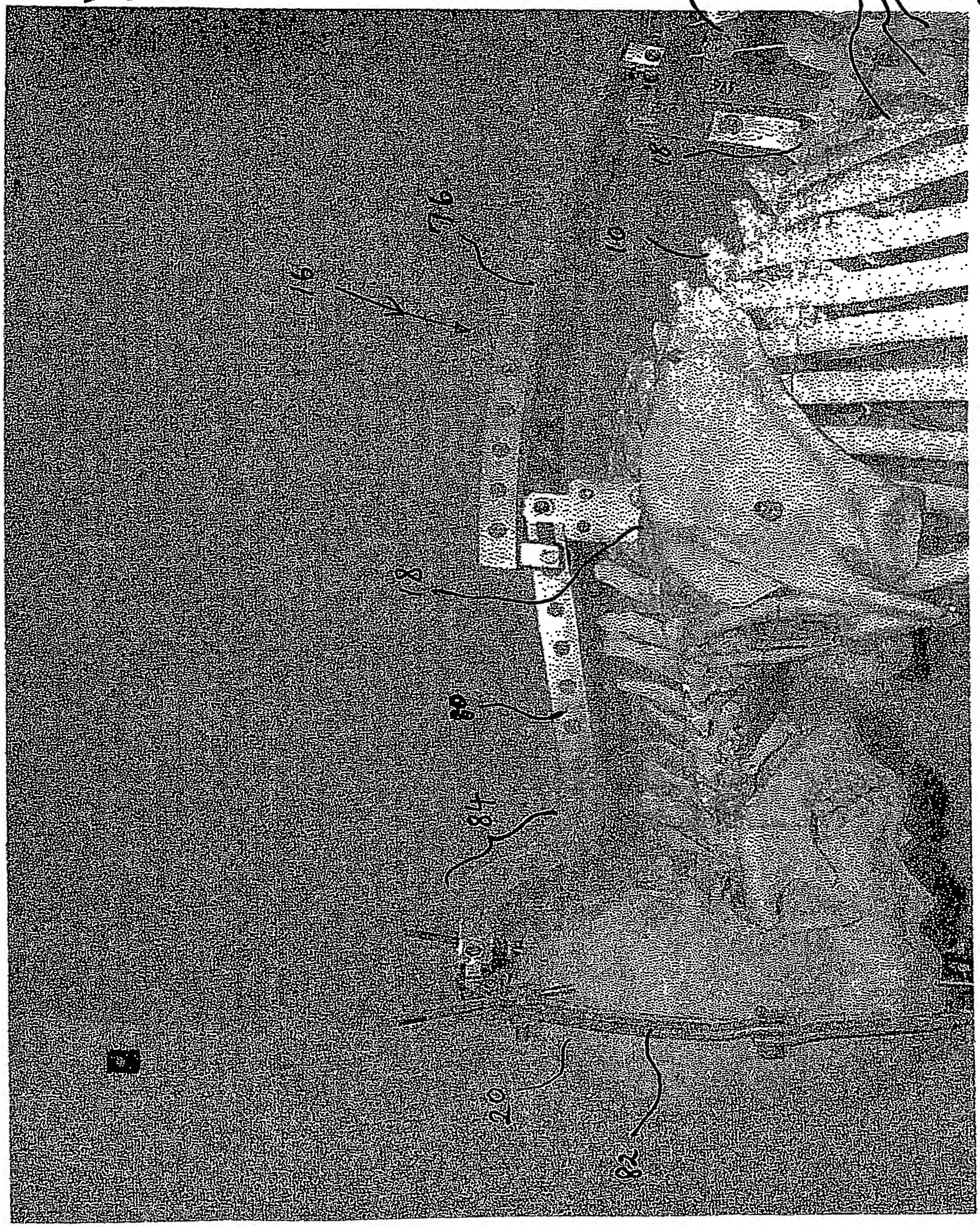


Fig. 1

Fig. 2.

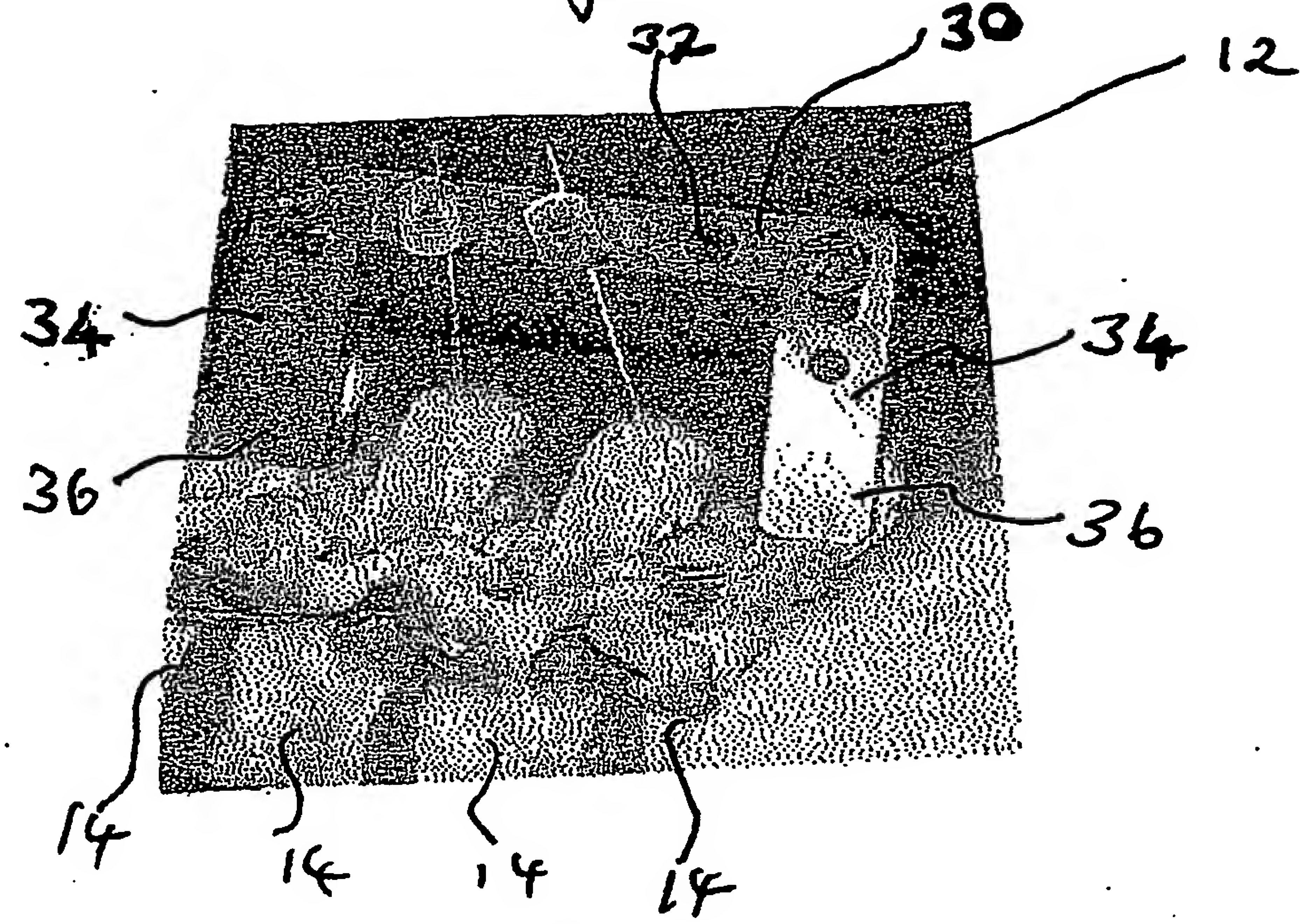
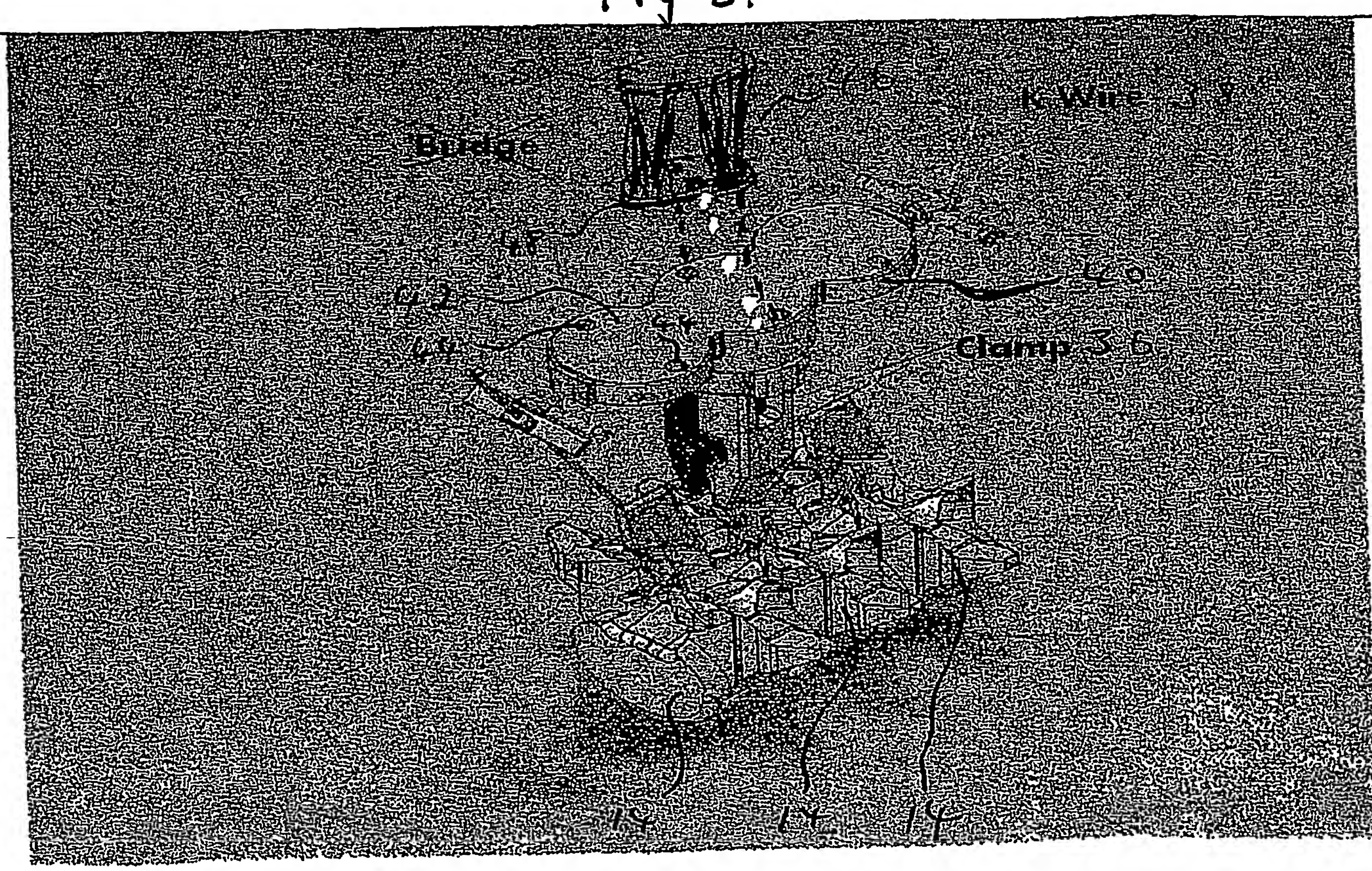


Fig 3.



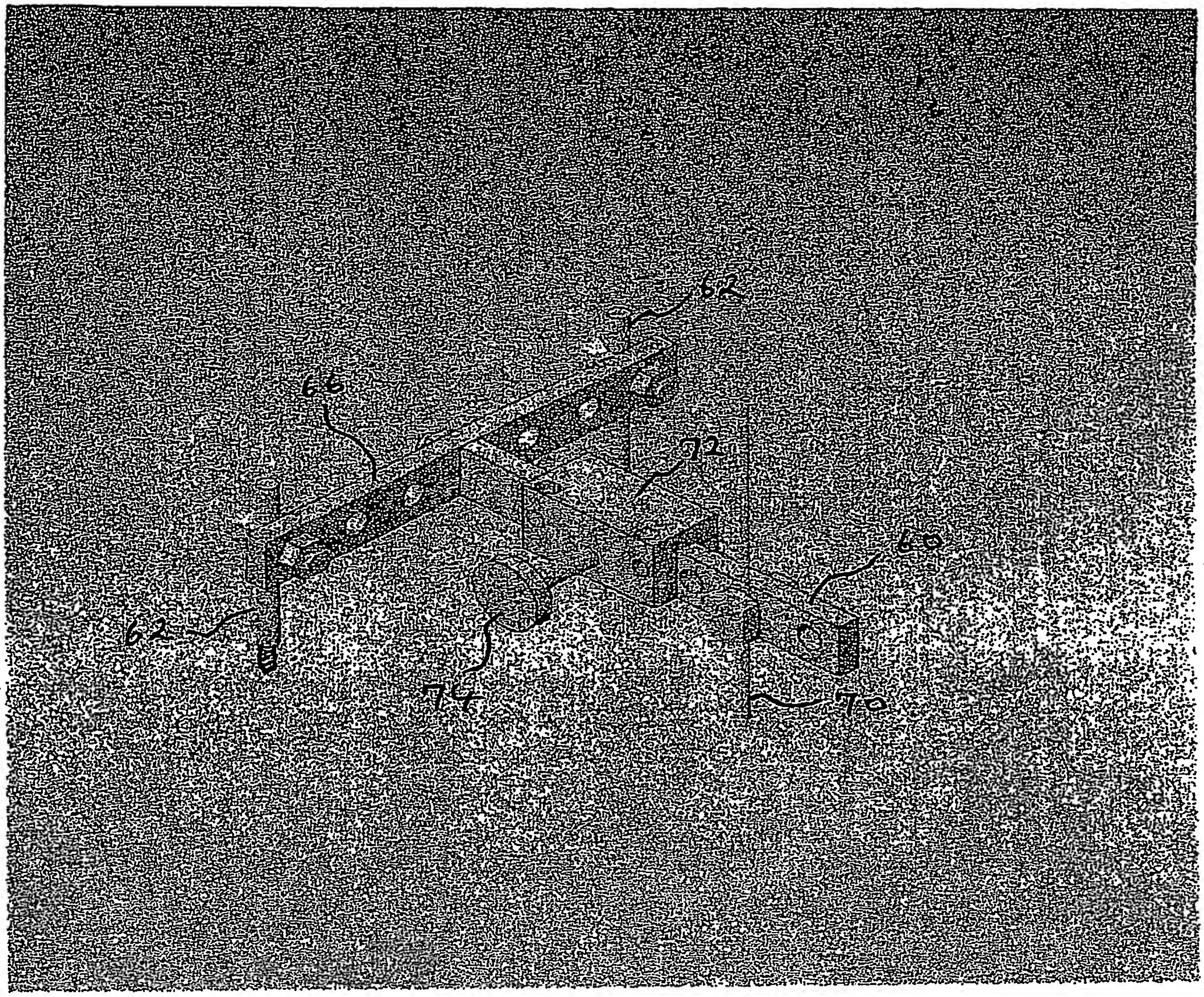


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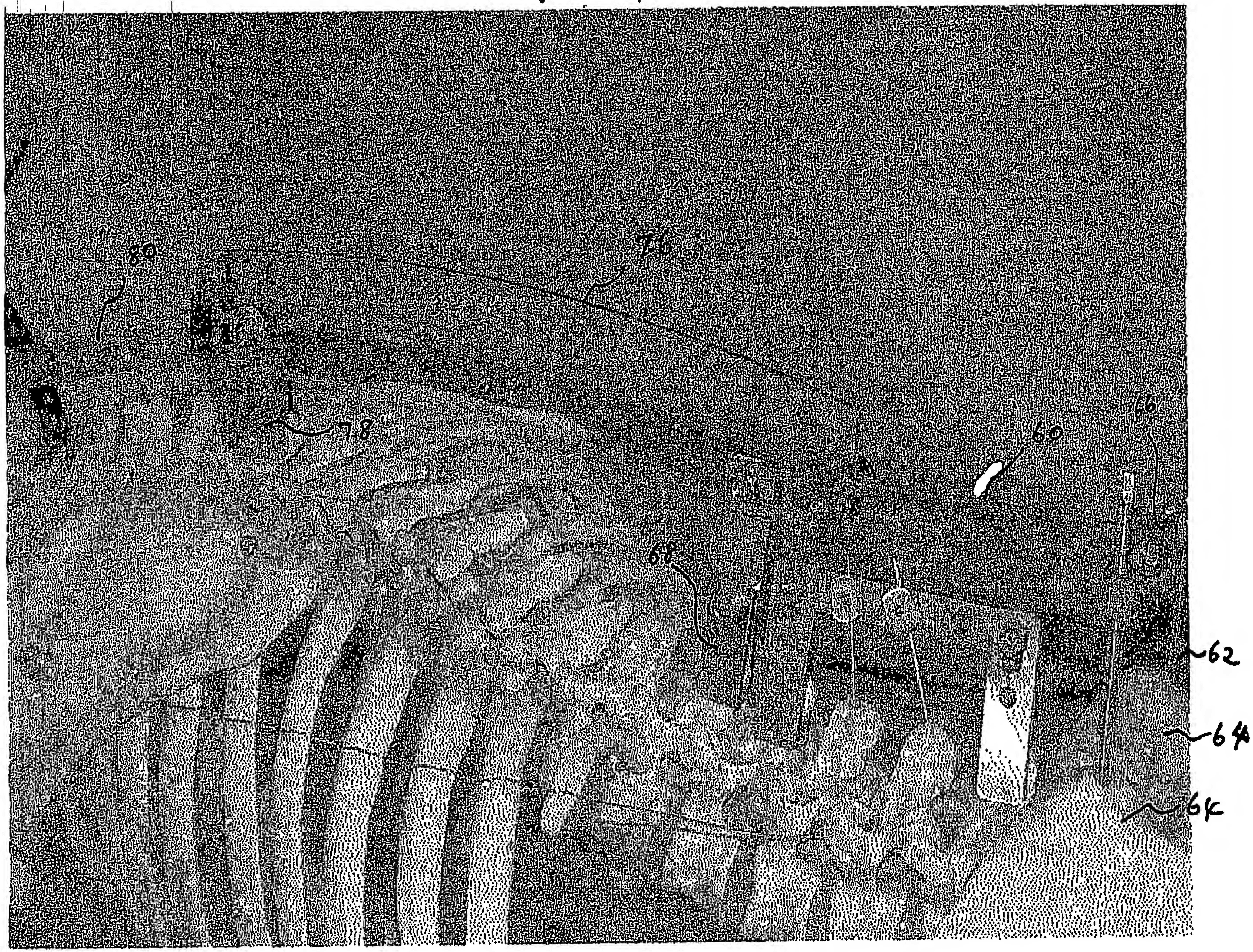
Fig. 5



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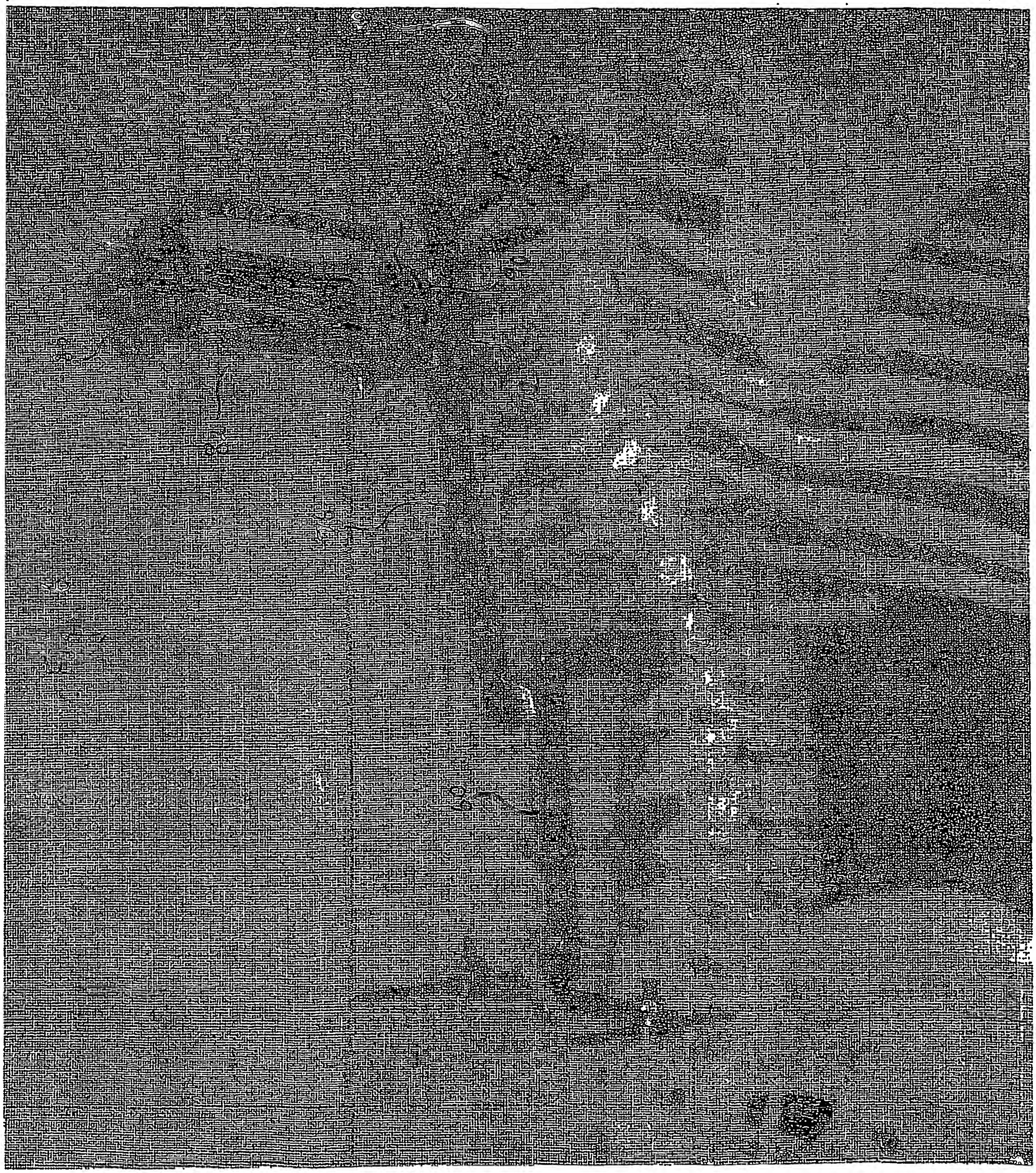

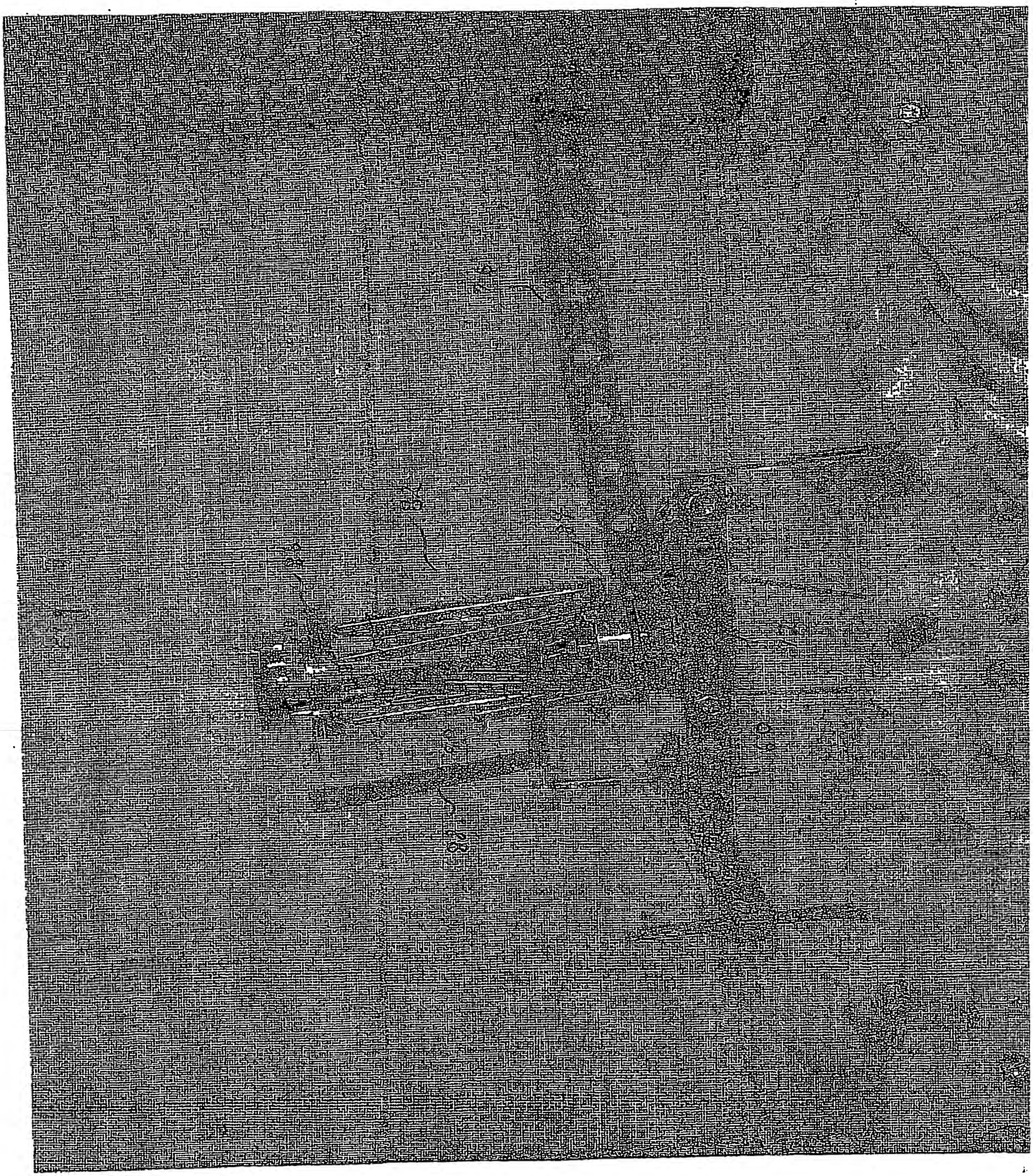

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